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Microscale vegetation-soil feedback boosts hysteresis in a regional vegetation-climate system

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It has been hypothesized that the Sahara can have two alternative stable states: a vegetated state and a desert state. Between both states sudden regime shifts may take place. This phenomenon can be explained by a regional scale positive feedback between the vegetation and the monsoon circulation. Apart from this regional scale feedback there is also a positive feedback between water and vegetation that acts on a smaller scale. This feedback may cause vegetation pattern formation and alternative stable states and is usually neglected in climate studies.

We combine both feedbacks in a simple model of climate-vegetation interaction. We adapted an existing small-scale model describing spatial distribution of water by adding a relation between vegetation cover and precipitation that is derived for the whole Sahara. Subsequently, we study the effect of different assumed strengths of this relation.

We show that inclusion of the micro-scale feedback between soil and vegetation greatly amplifies the non-linearity, causing alternative stable states and considerable hysteresis even if the effect of vegetation on precipitation is moderate. On the other hand, the range of conditions for which vegetation patterns are generated by the micro-

scale feedback decreases significantly due to the regional scale feedback. This implies that in monsoon areas such as the Western Sahara self-organized vegetation patterns are predicted to be less common than in areas without monsoon circulation such as Central Australia.